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SPECTRAL DISTRIBUTION OF ILLUMINATION FROM A CLEAR SKY ON A HORIZONTAL SURFACE

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[Translated by Alexander Breese from *Aerosiemka*, published by the Research Institute for Aerial Photography, Leningrad, 1934]

The observations here described were carried out during the summer of 1932 at Polkovo, U. S. S. R., with a quartz spectrograph. Spectrograms were taken of the light coming from horizontally placed milk-white matte glass, illuminated alternately by total illumination from the sun and clear sky ($E+e$) and by the clear sky alone (e). To make the latter measurements the glass was shaded from the sun's rays by a cardboard screen.

The collimator of the spectrograph was set at an inclination of 45°, with its axis directed along the azimuth 90° from the sun's position. In order to obtain characteristic curves a photometric screen with 12 apertures of different sizes was placed along the optical axis of the collimator 104 mm. distant from the apertures and at a right angle to the axis. By sliding the screen and placing the apertures of different sizes on the axis of the collimator, the opening of its objective to a previously determined ratio was effected.

Data regarding conditions under which the spectrograms were made are given in table 1. Illumination from the sun alone is designated as E, and from the sky alone as e. As may be seen from the table, the observations of E and e were not obtained simultaneously, which results in a slight error. However, as the differences in the zenith distance of the sun, Z, during each pair of observations of E and e are very small, the resulting error has practically no significance.

The spectrograms were worked up by V. T. Drury with the aid of a Hartman's microphotometer. All basic computations were also made by her. From the data obtained I computed the ratio of $\frac{e}{E+e}$ which characterizes the part played by the sun in total illumination from sun and sky. The values obtained for $\frac{e}{E+e}$ are given in tables 2 and 3.

From the data given in table 3 graphs were prepared for all 19 wavelengths observed, by plotting Z as abscissa and $\frac{e}{E+e}$ as ordinate. As the values of sec Z in the first five columns of table 3 are very close, only their mean is taken and used in graphs. Smoothed curves connect the points thus obtained. In drawing these curves the highest possible magnitude of $\frac{e}{E+e}$, which cannot exceed unity, was used as a guide. A few cases on July 8, where $\frac{e}{E+e}$ appears to be more than one, are to be accounted for by errors, either in the negative plate or in taking measurements. Four typical curves of the type described above are given in figure 1.

It will be noted on this figure that several points are considerably off the curve. This may be a result of errors of observation or due to the changes in the state of the sky. The latter occurred probably at sec Z=2.020 because for all 19 wavelengths the observed $\frac{e}{E+e}$ is considerably higher than it should be according to the curves.

TABLE 1

Observation time given at mean Pulkovo time				All exposures are 20 seconds			
Time	Observations July 6, 1932			Time	Negatives good		
	Obser-vation	Z	Z Mean		Obser-vation	Z	Z Mean
h *m*				*h* *m*			
13 52.8 54.7	$\frac{E+e}{e}$	41°40′ 41°50′	41°45′	17 28.8 31.2	$\frac{E+e}{e}$	66°05′ 66°23′	66°14′
14 15.7 17.5	$\frac{E+e}{e}$	43°37′ 43°47′	43°42′	18 1.5 3.2	$\frac{E+e}{e}$	70°10′ 70°23′	70°16′
14 36.7 37.8	$\frac{E+e}{e}$	45°38′ 45°45′	45°42′	18 28.5 30.0	$\frac{E+e}{e}$	73°28′ 73°39′	73°34′
16 34.7 36.5	$\frac{E+e}{e}$	59°18′ 59°30′	59°24′	18 57.0 59.0	$\frac{E+e}{e}$	76°50′ 77°04′	76°57′
17 2.0 4.3	$\frac{E+e}{e}$	62°44′ 63°00′	62°52′	19 50.8 52.5	$\frac{E+e}{e}$	82°49′ 82°59′	82°54′
Time	Observations July 8, 1932			Time	Negatives perfect		
	Obser-vation	Z	Z Mean		Obser-vation	Z	Z Mean
h *m*				*h* *m*			
11 9.1 11.9	$\frac{E+e}{e}$	38°30′ 38°22′	38°26′	16 15.1 18.1	$\frac{E+e}{e}$	57°14′ 57°36′	57°25′
11 39.1 41.3	$\frac{E+e}{e}$	37°33′ 37°30′	37°32′	16 39.1 41.1	$\frac{E+e}{e}$	60°18′ 60°28′	60°20′
11 52.1 12 0.1	$\frac{E+e}{e}$	37°19′ 37°18′	37°18′	17 5.1 8.1	$\frac{E+e}{e}$	63°30′ 63°52′	63°41′
12 29.1 31.8	$\frac{E+e}{e}$	37°36′ 37°40′	37°38′	17 30.1 33.1	$\frac{E+e}{e}$	66°38′ 67° 0′	66°49′
12 59.1 13 1.8	$\frac{E+e}{e}$	38°38′ 38°45′	38°42′	17 57.1 59.1	$\frac{E+e}{e}$	70°00′ 70°15′	70°08′
13 29.1 31.1	$\frac{E+e}{e}$	40°18′ 40°26′	44°22′	18 19.1 23.1	$\frac{E+e}{e}$	72°41′ 73°10′	72°56′
13 59.3 14 2.1	$\frac{E+e}{e}$	42°33′ 42°48′	42°40′	18 40.1 42.4	$\frac{E+e}{e}$	75°13′ 75°30′	75°22′
14 29.1 32.1	$\frac{E+e}{e}$	45°16′ 45°34′	45°25′	18 59.1 19 1.1	$\frac{E+e}{e}$	77°27′ 77°40′	77°34′
14 59.1 15 1.1	$\frac{E+e}{e}$	48°21′ 48°35′	48°28′	19 20.1 22.1	$\frac{E+e}{e}$	79°50′ 80°03′	79°56′
15 51.1 54.1	$\frac{E+e}{e}$	54°19′ 54°40′	54°30′	19 40.1 43.1	$\frac{E+e}{e}$	82°01′ 82°20′	82°10′

From the plotted curves the values of $\frac{e}{E+e}$ are taken for the round values of sec Z. These values are given in

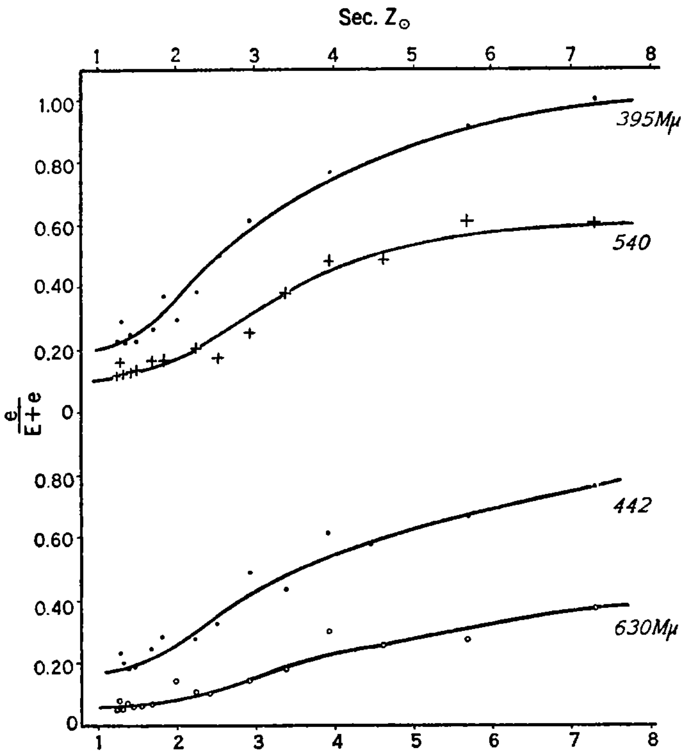

TABLE 2

Z Sec. Z	41°45′ 1.340	43°42′ 1.383	45°42′ 1.432	59°24′ 1.964	62°52′ 2.193	66°14′ 2.481	70°16′ 2.961	73°34′ 3.535	76°57′ 4.429	82°54′ 8.091
λ	e : (E+e)									
355	0.257	0.430	- - - -	- - - -	0.542	0.796	0.594	0.716	- - - -	- - - -
395	.257	.244	0.204	0.242	.316	.750	.397	.470	0.596	0.918
405	.313	.290	.230	.294	.365	.496	.444	.502	.682	.875
411	.234	.248	.243	.335	.291	.430	.340	.397	.548	.813
418	.221	.193	.152	.254	.262	.443	.371	.369	.631	.733
425	.221	.213	.194	.259	.282	.362	.386	.361	.578	.726
442	.197	.204	.158	.228	.236	.415	.358	.384	.607	.776
463	.167	.164	.151	.285	.268	.378	.335	.369	.521	.800
489	.175	.166	.132	.203	.262	.290	.278	.317	.380	.703
499	.171	.172	.133	.226	.232	.315	.249	.322	.457	.617
520	.152	.155	.143	.228	.250	.268	.312	.338	.380	.733
540	.155	.155	.141	.162	.190	.246	.239	.262	.398	.582
560	.122	.139	.106	.199	.194	- - - -	.219	.265	.320	.482
580	.120	.121	.105	.161	.166	.200	.200	.218	.283	.484
599	.099	.089	.092	.202	.188	.170	.220	.248	.261	.367
615	.085	.084	.086	.157	.166	.152	.163	.199	.229	.300
630	.097	.074	.081	.162	.174	.155	.158	.204	.216	.355
646	.079	.078	.078	.132	.155	.142	.155	.163	.187	.266
665	.084	.086	.082	.141	.141	.119	.148	.170	.250	.373

table 4. As may be seen from table 4, the values of $\frac{e}{E+e}$ in each column follow in general a very definite trend according to the wavelength λ. However, in certain cases deviations are more or less considerable. For the most part these inconsistencies are probably due to errors of observation, but it is possible that some of them actually exist and may be related to the fact that the spectral absorption coefficients of the atmosphere for certain wavelengths may vary, as happens for instance in the ozone absorption bands. Much more extensive observations are needed to reach definite conclusions.

As has already been indicated, table 4 is based on observations of one day only, namely, on July 8, 1932. The observations made on July 6 give noticeable differences from the curves for July 8. There is no doubt that $\frac{e}{E+e}$ depends to a great extent upon the condition of the atmosphere, even if the sky seems to be cloudless. Only continuous spectral observations made at different places will make possible the construction of a complete picture of this phenomenon.

The principal conclusions that can be drawn from the data already available may be summarized as follows:

1. The part the clear sky has in the illumination on a horizontal surface rapidly increases at every wavelength with increase of zenith distance of the sun.
2. The influence of the clear sky with the same Z rapidly increases with decrease of λ.
3. In the ultraviolet part of the spectrum, with a large Z the illumination on the horizontal surface results exclusively from the sky $\left(\frac{e}{E+e}=1\right)$, with the sun's influence dwindling to zero. This gives an explanation of the well-known fact that an object photographed under such conditions does not produce a shadow.

TABLE 3

Z Sec Z	38°26′ 1.276	37°32′ 1.261	37°18′ 1.257	37°38′ 1.263	38°42′ 1.281	37°56′ 1.268	40°22′ 1.313	42°40′ 1.360	45°25′ 1.425	48°28′ 1.508
λ	e : (E+e)									
355 mμ	0.344	0.390	0.320	0.316	0.367	0.347	0.496	0.348	0.406	0.306
395	.226	.200	.258	.240	.265	.238	.303	.234	.254	.237
405	.258	.290	.299	.261	.247	.271	.292	.255	.257	.300
411	.220	.246	.263	.221	.264	.243	.283	.284	.250	.269
418	.199	.199	.211	.220	.219	.210	.246	.194	.252	.206
425	.214	.233	.214	.205	.231	.219	.261	.240	.221	.239
442	.208	.176	.214	.203	.182	.197	.250	.218	.205	.204
463	.200	.160	.186	.202	.194	.188	.204	.216	.198	.208
489	.152	.138	.172	.156	.140	.152	.197	.149	.171	.173
499	.143	.160	.164	.164	.157	.158	.168	.164	.146	.203
520	.122	.126	.142	.148	.141	.141	.136	.177	.130	.174
540	.117	.138	.125	.127	.123	.126	.173	.134	.140	.142
560	.098	.106	.132	.099	.124	.112	.149	.114	.134	.140
580	.097	.109	.112	.101	.103	.104	.150	.118	.116	.116
599	.078	.082	.093	.080	.102	.087	.126	.084	.085	.096
615	.067	.065	.084	.065	.073	.071	.114	.081	.085	.083
630	.066	.071	.078	.068	.076	.072	.100	.071	.092	.083
646	.048	.048	.065	.062	.060	.057	.090	.065	.065	.077
655	.085	.088	.090	.085	.096	.089	.104	.085	.091	.102

Z Sec Z	54°30′ 1.722	57°25′ 1.857	60°20′ 2.020	63°41′ 2.256	66°49′ 2.540	70°08′ 2.942	72°56′ 3.407	75°22′ 3.958	77°34′ 4.645	79°56′ 5.721	82°10′ 7.337
λ	e : (E+e)										
355 mμ	0.533	0.935	0.847	0.791	0.807	0.968	1.02	0.993	0.776	1.11	1.16
395	.279	.381	.540	.394	.507	.620	0.556	.773	.703	0.916	1.02
405	.324	.446	.501	.385	.373	.564	.670	.687	.736	.730	0.746
411	.285	.377	.552	.359	.351	.484	.555	.698	.653	.725	.753
418	.271	.375	.525	.369	.347	.485	.590	.622	.573	.771	.830
425	.286	.332	.547	.292	.292	.415	.472	.578	.590	.594	.899
442	.260	.302	.474	.297	.343	.502	.451	.630	.610	.682	.776
463	.264	.264	.367	.372	.336	.414	.489	.784	.632	.792	.774
489	.183	.198	.370	.240	.243	.330	.451	.424	.518	.679	.731
499	.183	.210	.409	.269	.226	.344	.362	.542	.489	.527	.659
520	.209	.196	.322	.300	.226	.354	.574	.667	.518	.573	.748
540	.180	.180	.304	.217	.188	.269	.396	.491	.496	.612	.607
560	.145	.165	.296	.183	.189	.229	.313	.458	.397	.375	.572
580	.142	.162	.276	.164	.167	.235	.262	.396	.386	.388	.593
599	.110	.124	.225	.150	.143	.178	.232	.431	.346	.356	.465
615	.100	.115	.186	.164	.143	.159	.256	.451	.313	.601	.483
630	093	.095	.160	.132	.132	.173	.201	.319	.277	.294	.388
646	.084	.087	.141	.118	.124	.164	.220	.371	.251	.305	.416
665	.124	.215	.225	.150	.140	.230	.240	.272	.500	.397	.371

TABLE 4

Sec. Z Z	1.2 33°34′	1.6 51°19′	2.0 60°0′	2.5 66°25′	3.0 70°32′	3.5 73°24′	4.0 75°31′	5.0 78°28′	6.0 80°24′	7.0 81°47′
λ	e : (E+e)									
355 mμ	0.30	0.48	0.68	0.87	0.98	1.00	1.00	1.00	1.00	1.00
395	.23	.28	.37	.50	.61	0.69	0.75	0.85	0.94	0.98
405	.23	.30	.38	.49	.58	.65	.68	.72	.74	.75
411	.25	.28	.32	.40	.49	.57	.62	.69	.73	.75
418	.20	.24	.30	.38	.47	.56	.63	.72	.78	.82
425	.22	.25	.29	.35	.42	.49	.55	.65	.72	.78
442	.19	.22	.27	.36	.45	.51	.56	.64	.70	.76
463	.19	.22	.26	.34	.42	.51	.57	.66	.72	.77
489	.15	.18	.21	.27	.34	.40	.46	.55	.63	.71
499	.15	.17	.20	.26	.31	.38	.43	.52	.58	.64
520	.13	.17	.22	.29	.38	.46	.52	.60	.65	.68
540	.12	.15	.19	.25	.32	.41	.47	.54	.58	.60
560	.13	.14	.16	.20	.25	.31	.37	.46	.52	.56
580	.11	.12	.14	.18	.24	.29	.34	.40	.45	.49
599	.08	.09	.11	.14	.18	.24	.29	.37	.42	.45
615	.08	.09	.11	.15	.21	.27	.33	.40	.45	.48
630	.08	.09	.10	.14	.18	.22	.25	.30	.34	.38
665	.08	.10	.13	.16	.20	.25	.29	.35	.38	.40